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AIR FORCE HUMAN RESOURCES LABORATORY

EVALUATION OF AN AIRBORNE AUDIO-VIDEO RECORDING SYSTEM FOR AIRCRAFT EQUIPPED WITH HEAD-UP DISPLAY

By

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FLYING TRAINING DIVISION
Williams Air Force Base, Arizona

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13. ABSTRACT

Recent innovations in flying training, most notably the technique of audio-video recording, suggest a very promising approach to the training of fighter pilots. The objective of this project was to provide a low-cost, reliable audio-video recording system (AVRS) for aircraft equipped with Head-Up Display (HUD) that would be capable of recording both the external real world cues through the aircraft's forward windscreen as well as the symbology of the HUD projected on the aircraft's combining glass. The ultimate objective is a research program to assess audio-video recording in HUD-equipped aircraft as both a technique for improvement of training and as a tool for pilot proficiency assessment. Two A-7D aircraft were fitted with an AVRS constructed from low-cost, commercial equipment with a good record of reliability. The equipment was modified to make it compatible with the aircraft and its flight environment. The system proved capable of recording the symbology on the HUD, as well as resolving ground targets at normal altitudes and slant ranges encountered in the training environment. Although the equipment is quite acceptable for the purpose intended, it was not concluded on the basis of this study that this particular engineering design would be satisfactory for fleet-wide retrofit. Deficiencies that are acceptable for a research program might prove completely unacceptable for an operational system.

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AIR FORCE HUMAN RESOURCES LABORATORY
AIR FORCE SYSTEMS COMMAND
Williams Air Force Base, Arizona

FOREWORD

This work was conducted under Project 1123, Flying Training Development, Task 112301, Development of Performance Measurement Techniques for Air Force Flying Training. Dr. William V. Hagin was Project Scientist, Mr. Milton E. Wood was Task Scientist, and Maj Joe A. Fitzgerald was the Technical Monitor.

The video engineering modifications, installation, and equipment data were provided by Conductron Corporation, St. Charles, Missouri, under Contract F41609-70-C-0035. Mr. G. F. Mussmann was the Project Engineer for Conductron.

Flying test and engineering evaluation of the airborne audio-video recording system were carried out by the USAF Tactical Fighter Weapons Center (USAF TFWC) in conjunction with the 57th Fighter Weapons Wing, Detachment 1, Luke Air Force Base, Arizona. The test manager for USAF TFWC was Maj Loren D. Eastburn. The test project pilot for Detachment 1 was Capt Lennis L. Higgins. The test was carried out under the authority of TAC Test Order 70A-112F, dated 17 September 1970.

The author wishes to acknowledge the valuable contributions to this research provided by Maj Eastburn and Capt Higgins.

This report has been reviewed and is approved.

George K. Patterson, Colonel, USAF
Commander

ABSTRACT

Recent innovations in flying training, most notably the technique of audio-video recording, suggest a very promising approach to the training of fighter pilots. The objective of this project was to provide a low-cost, reliable audio-video recording system (AVRS) for aircraft equipped with Head-Up Display (HUD) that would be capable of recording both the external real world cues through the aircraft's forward windscreen as well as the symbology of the HUD projected on the aircraft's combining glass. The ultimate objective is a research program to assess audio-video recording in HUD-equipped aircraft as both a technique for improvement of training and as a tool for pilot proficiency assessment. Two A-7D aircraft were fitted with an AVRS constructed from low-cost, commercial equipment with a good record of reliability. The equipment was modified to make it compatible with the aircraft and its flight environment. The system proved capable of recording the symbology on the HUD, as well as resolving ground targets at normal altitudes and slant ranges encountered in the training environment. Although the equipment is quite acceptable for the purpose intended, it was not concluded on the basis of this study that this particular engineering design would be satisfactory for fleet-wide retrofit. Deficiencies that are acceptable for a research program might prove completely unacceptable for an operational system.

SUMMARY

Fitzgerald, J. A. *Evaluation of an airborne audio-video recording system for aircraft equipped with head up display.* AFHRL-TR-71-20. Williams AFB, Ariz.: Flying Training Division, Air Force Human Resources Laboratory, May 1971.

Problem

The purpose of this project was to develop, install, and perform engineering evaluation of a low-cost, reliable audio-video recording system for the A-7D aircraft that would be capable of recording Head-Up Display symbology as well as outside real world cues. The equipment had to be capable of resolving ground targets at altitudes and slant ranges encountered in the training environment.

Approach

The project was conducted in four phases. During the first phase the contractor designed an audio-video recording system for the A-7D. The design requirements specified use of commercial off-the-shelf equipment. Such equipment had to be low in cost and high in reliability. The second phase provided for procurement and modification of the equipment as necessary to conform to the engineering design. Next, the AVRS was installed in two A-7D aircraft. The final phase provided for completion of flight test and engineering evaluations.

Results

Although initially plagued with difficulties, both systems ultimately provided acceptable video tapes. Cost was kept within programmed limits, and equipment reliability and performance met desired standards.

Conclusions

With slight modifications, low-cost, commercial audio-video equipment can be made to operate reliably and effectively in the stringent flight environment of a fighter aircraft.

This summary was prepared by Joe A. Fitzgerald, Combat Crew Training Branch, Flying Training Division, Air Force Human Resources Laboratory.

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I. BACKGROUND

Previous Research

This project is the third effort of the Air Force Human Resources Laboratory in the development of low-cost audio-video recording systems (AVRS) for use in flying training research. In the initial effort conducted between September 1967 and July 1969 under an Air Force contract,[1] an AVRS for the T-37 aircraft was designed, installed, and checked out. Subsequently training research was performed utilizing the equipment. The work was conducted at Vance Air Force Base, with Undergraduate Pilot Training students as the test subjects.

The AVRS for that project incorporated off-the-shelf components, but major engineering modifications were required to adapt the system for airborne operation in the T-37 aircraft. The audio-video recorder unit recorded on 1/2-inch 1 mil tape, giving a total recording time from the 4-1/2-inch reel of approximately 22 minutes. Two vidicon cameras were used in the aircraft: one camera was mounted to view selected portions of the instrument panel and the other provided a forward view through the windscreen, as closely as possible approximating the pilot's eye view. The audio-video recorder, a Sony Model DVK2400, operated on battery power. This model was selected because it was the only off-the-shelf portable recorder which would fit the installation space available in the aircraft. The resolution of the recorder was approximately 200 lines. Studies utilizing the equipment demonstrated improved achievement levels and apparently faster learning rates for students trained with the AVRS (Schumacher, Rudov, & Valverde, 1970).

Because of the encouraging results of the work at Vance Air Force Base on the T-37, the studies of airborne AVRS were continued.[2] After some modification, equipment used in the Vance project was installed in an F-4E at Nellis Air Force Base. The purpose of this later test was to establish the feasibility, quality, and utility of audio-video tape recordings as a fighter flight training and documentation technique (Klamm, Jacobs, & Clark, 1970).

The two television camera systems allowed simultaneous recording by splitting the TV display of the scene viewed through the gunsight and the indications of the principal flight instruments. Audio-video tapes were obtained of air-to-ground weapon delivery, dart attack, air combat maneuvering, simulated nuclear weapons delivery, and close air support missions.

A number of problems were encountered which caused this project to be somewhat less successful than the Vance work. One of the major problems was related to the fact that battery power was utilized rather than aircraft power. In some instances, the batteries were not fully recharged, had corroded leads, or were improperly installed. However, this problem was corrected during the test by converting the system to aircraft power. Another major source of problems was the fragile structure of the base housing the videocorder. The base did not provide adequate protection for the electronic components, and dents in the case often restricted tape movement so that usable recordings were not obtained. Still another problem area was the reflections from instrument glass covers which frequently impeded reading of the instruments. Finally, video tape playback resolution was below that level required for detailed mission assessment. Because of these problems and others, the results were not as definitive as had been expected. However, the project did prove that reasonably good video tapes could be obtained under the high vibration and g-load conditions of a fighter-type aircraft using low-cost, commercial equipment. The experience gained from both the Vance and the Nellis projects paved the way for the development of the A-7D AVRS.

Comparison of Audio-Video and Motion Picture Recording

Audio-video recording (AVR) offers many advantages over motion picture recording (MPR)

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[1] Work sponsored by the Training Research Division of the Air Force Human Resources Laboratory conducted under Contract F33615-68-C-1048 by American Institutes for Research, Pittsburgh, Pennsylvania, and Conductron Corporation, St. Charles, Missouri.

[2] Work sponsored by the Training Research Division of the Air Force Human Resources Laboratory conducted under Contract F33615-69-C-1816 with Conductron Corporation, St. Charles, Missouri.

as well as some distinct disadvantages. Some of the notable differences between the two modes are briefly discussed.

Running Time. The running time for AVR is a function of the kind of equipment selected but is much longer than that of the 16mm cameras now in use. For example, the Sony AV3400 video recorder used for the A-7D AVRS has approximately a 30-minute tape capacity. The N-9 gun camera used in the F-100 aircraft has 1.3 minutes of film capacity at 32 frames per second. The experimental Milliken camera (DBM-2A) for the A-7D has six minutes of film capacity at 16 frames per second.

Light Level Adaptation. TV cameras are capable of adapting automatically to a wide range of light levels. A typical range is 30 to 10,000 foot candles, the automatic sensitivity range of the Sony Model AV3400 video camera. Motion picture cameras in use today in fighter aircraft must be pre-set on the ground for the light level range expected in the target area. If the actual light level differs from that expectation, the quality of the film will suffer. On the other hand, the vidicon unit of the video camera can be damaged by excessive direct exposure to the sun's rays, although the vidicon unit will heal itself if the damage is not too great. Permanent damage can result in loss of vidicon sensitivity and retention of burned-in images.

Audio Recording. Recent video recorders such as the Sony AV3400 provide good quality audio recording. Such audio information can prove quite useful as an adjunct to the video information. For example, during a gunnery pass a student pilot can describe how he perceives the situation and what corrections he is attempting to make. This information can be very useful to the student and his instructor in diagnosing the source of errors.

Resolution. The resolution of lightweight AVR has been improving steadily over the years. However, it does not yet equal the resolution of high quality MPR. Whether or not the resolution is satisfactory depends on the intended use. The 200 line resolution of the T-37 AVRS designed for the Vance study was satisfactory for recording landing patterns, but the same resolution was not completely satisfactory in the Nellis study because it could not properly resolve the dart target for air-to-air gunnery, an important mission of the F-4E. The 300 line system of the A-7D AVRS can resolve quite satisfactorily the Head-Up Display (HUD) symbology, ground targets, run-in lines, and bomb circles. It can also resolve the dart target, although this was not a requirement since air-to-air is not a mission of the aircraft.

Time Delay from Mission Completion to Review. AVR tapes can be played immediately upon mission completion since no processing is required. This is an important characteristic because a student's recollection of mission details tends to diminish rapidly with time. Processing time for gun camera film can vary from about 15 minutes to hours, or even several days, depending on the kind of processing equipment available and the workload.

Complexity and Bulk. AVR equipment is more complex than MPR equipment and, therefore, is subject to more problems. AVR requires a recorder that, although relatively small, is much larger than a film cartridge. It also requires a control unit, a camera, and the associated wiring. By comparison, a 16mm gun camera is a relatively simple, self-contained unit. However, the bulkier items of AVR equipment such as recorder and control box can be remote from the cockpit, leaving only a small vidicon unit with its associated mirror and light baffle in the cockpit. With proper design of AVR equipment, then, restriction to forward visibility need not exceed that presented by a 16mm gun camera.

Color. Lightweight, low-cost, color AVR did not exist at the time this project was undertaken, but the present trend seems to indicate that such equipment will not be long in coming. Color could prove to be an important factor in future designs. On the other hand, high-quality 16mm color for gun camera systems is a present reality.

II. PROGRAM PLAN

The program for the present study consisted of four phases: design, development, installation and support, and evaluation.

Design. During the design phase measurements were obtained of the representative A-7D aircraft at Luke Air Force Base. In addition, installation data were obtained from Ling-Temco-Vought (LTV) Aerospace Corporation and from the A-7D simulator presently under construction by Conductron Corporation. Mechanical layout and detailed design were completed based on the data.

Development. During the development phase the Sony equipment was modified in accordance with the system design, and the explosion proof qualification was completed. It was not deemed

necessary to do further experimental testing because test data available on similar Sony equipment could be extrapolated to include the newer equipment.

Installation and Support. Two AVR systems were installed in the selected A-7D aircraft, and two weeks of field support were provided. This effort included instruction of Air Force personnel in the operation and maintenance of the AVRS.

Flight Test and Evaluation. Flight tests were performed to insure that engineering criteria were met and, further, to obtain reliability and maintainability information.

III. SYSTEM DESCRIPTION

The A-7D AVRS was designed to use only low-cost commercial equipment. This was a reasonably low-risk undertaking because experience gained on a similar design for the F-4E could be directly applied.

An important requirement was that the camera and optics should be as unobtrusive as possible. In compliance with this requirement, the feasibility of using fibre optics to remote the camera was investigated. Unfortunately, video transmitted through the fibre optics bundle tested was not of sufficient quality to justify its use.

The A-7D AVRS includes equipment installed in the aircraft and stationed on the ground. An illustration and several diagrams are included in the appendix to show the system components, their locations, and their interrelationships. Total weight of each aircraft-installed system including cables, brackets, and optics is 31 pounds, 11 ounces. Additionally, the system accommodates installation in either pre-D-27 or D-27 and subsequent A-7 aircraft. The airborne and ground based components of the system are briefly described.

Airborne Equipment

Video Tape Recorder. The video tape recorder is a modified Sony AV-3400 video recorder. The modifications included installation of a 12 VDC power supply to replace the batteries, modification of the recorder switching and mode control circuits to permit remote operation by the pilot, modification of the audio circuitry for compatibility with the A-7 intercom, removal of existing Sony connectors and replacement with military-type connectors, and modification of outer case and cover to facilitate installation of the unit in the A-7 electronics equipment bay. The unit is approximately 6 inches in height, 10-1/2 inches in width, and 11-1/2 inches in depth.

Camera Control Unit. The camera control unit is a modified Sony AVC-3400 video camera. The modifications included removal of the vidicon assembly, deflection yoke, and focus coils, removal of the audio microphone and associated electronics, modification of switching and remote control circuitry, disablement of the first three stages of video amplification, removal of the existing Sony umbilical cable and replacement with military-type connectors, and modification of the outer cover to facilitate installation of the unit in the A-7 aircraft. The control unit is 2-1/2 inches in width, 8-1/2 inches in length, and 5 inches in height. The weight is 4 pounds, 1 ounce.

Vidicon Unit. The vidicon unit consists of the vidicon, the deflection yoke and focus coils removed from the control unit assembly, a three-stage video preamplifier board, a system remote control switch, and system operating mode indicators. All parts were enclosed in a 2 by 2 by 5-inch section of aluminum tubing with a military-type signal connector mounted on one end and camera lens C-mount adapter on the other. Four mounting studs were brought out the bottom to facilitate installation of the unit in the A-7 cockpit. Weight of the vidicon unit is 2 pounds, 9 ounces including its mounting brackets.

System Optics. The optics include a 25mm, F1.9 to F22, 2 feet through infinity, C-mount Cosmicar Lens (model 2519), a 1/4-inch thick, 2.2-inch wide, and 3.5-inch high combining glass and mount, and a 1/8-inch thick, approximately 2 by 3-inch combining glass light baffle. The weight of these assemblies is 12 ounces.

System Cables. The system cabling consists of one standard neoprene-covered power cable, one recorder to control unit cable with audio adapter for gaining access to the aircraft intercom system, one control unit to vidicon unit cable, and one control unit to alignment monitor cable. All cables were terminated with military-type connectors. Wire bundles were covered first with nylon tape, then with a double thickness of 1-inch braided conductive shielding tape, and finally with an appropriate size clear vinyl flexible tubing; they were identified with chicken bands at appropriate places. Total weight of aircraft installed cables is 5 pounds, 14 ounces.

Ground Based Equipment

Alignment Monitor. The alignment monitor is a modified Symphonic TPS 5050 5-inch battery or

AC operated, commercial grade television receiver. The modifications included removal of the external earphone audio circuitry and use of the jack to provide a switching connection to disable the normal broadcast video signal and permit injection of the AVRS video when the monitor is used on the flight line for system boresighting and alignment. When not in use for AVRS alignment, the monitor can be operated as a conventional broadcast TV receiver.

Playback Unit. The playback unit is an unmodified Sony AV-3600 videocorder which is compatible with the video tape recordings produced by the airborne video tape recorder. The unit operates on 115V 60-Hz power, it is self-contained, and in conjunction with the 18-inch ground monitor of the 3-inch alignment monitor, it provides the ground base equipment necessary to play back and evaluate the in-flight video recordings.

Playback Monitor. The playback monitor is an unmodified Sony CVM 180/U, 18-inch, AC operated television receiver and video tape monitor. The monitor is capable of playing back audio and video signals either directly from the airborne recorder with a special cable or directly from the AV-3600 playback recorder with the cable provided. Additionally, when not in use for AVRS purposes, the monitor can be operated as a conventional broadcast TV receiver.

IV. RESULTS AND DISCUSSION

The objective of the project was to obtain a low-cost, reasonably reliable AVRS that, when installed in the A-7D, would provide video of sufficient resolution to record all HUD symbology as well as the outside world cues of primary interest. This was the first phase of a two-phase effort. The second phase is to evaluate the equipment as a method for improving quality of training and for possible use in pilot proficiency assessment. With a few reservations it can be fairly stated that the objective of the project was met. A number of deficiencies were encountered, and some of these were corrected during the test. Although other deficiencies still remain unresolved, it is not felt that they will prevent the satisfactory conclusion of the evaluation phase. A discussion of these problem areas follows. It is not all inclusive but covers the more significant deficiencies.

Boresight. It proved to be quite difficult to obtain a boresight which could capture all HUD symbology. The symbology in the upper right quadrant was not recorded with the aircraft combining glass in the forward position. A slightly larger mirror improved but did not eliminate the problem. However, the loss can be reduced to an acceptable level by careful boresight.

Vidicon Burning. Direct exposure to the sun will cause burned-in images to the vidicon. Although they cannot be prevented, they can be reduced by keeping a lens cover on the lens when the camera is not in use. These burns did not prove to be a serious problem since they were found to heal within a very short time.

Light Level Adaptation. It was found that the vidicon automatic gain control could not sufficiently compensate for high light levels. When the system was exposed to quite high light levels, the HUD symbology became very indistinct, and ground contrast was degraded. The video became washed out. The use of a medium green photographic filter improved video quality to an acceptable degree.

G-Effect. The video began to distort with the application of 3 g's and was unusable at 4 g's and above. Although experience has indicated that this problem can be eliminated by mounting the recorder in the vertical position, space limitations in the A-7D prevented such an installation. Since aircraft maneuvering can be completed with no more than 3 g's for those areas of primary interest, it is not a significant problem. In air-to-ground gunnery, for instance, the area of primary interest is the turn to final and the final itself when few g's are induced. The pullout or recovery when more than 3 g's are usually applied is of secondary interest.

Light Baffle. The glare shield did not cause video difficulties when it was properly aligned. Because it used only a single mounting screw, however, it tended to become misaligned. This problem was easily corrected by simply installing another screw. A more serious problem was distraction to the pilot. Although experienced pilots probably can cope with such distraction, it may be unwise to allow new student pilots to fly the test aircraft. Use of a polarized lens in conjunction with a polarized AVRS combining glass may alleviate the problem, and this technique is being investigated. If it is successful, need for the light baffle will be eliminated.

REFERENCES

Klamm, R.L., Jacobs, D., & Clark, H.J. *Training potential of inflight audio/visual recording equipment for the F-4E aircraft.* AFHRL-TR-70-25. Wright-Patterson AFB, Ohio: Advanced Systems Divisions, Air Force Human Resources Laboratory, December 1970.

Schumacher, S.P., Rudov, M.H., & Valverde, H.H. *Evaluation of a low cost in-flight audio/video recording system for pilot training.* AFHRL-TR-69-31. Wright-Patterson AFB, Ohio: Training Research Division, Air Force Human Resources Laboratory, January 1970.

APPENDIX ILLUSTRATION AND DIAGRAMS OF AUDIO-VISUAL RECORDING SYSTEM

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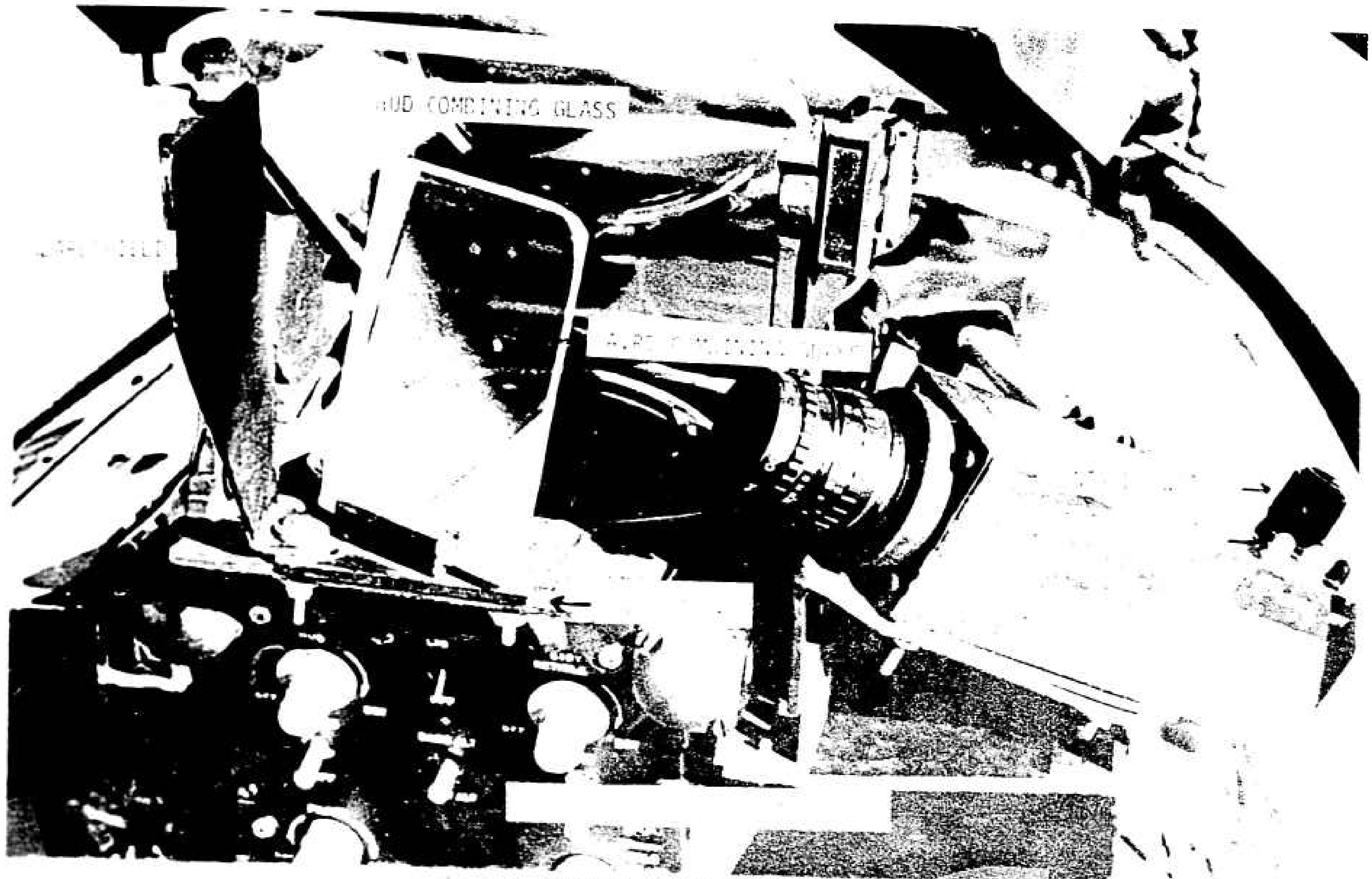

Combining glass and vidicon cockpit installation

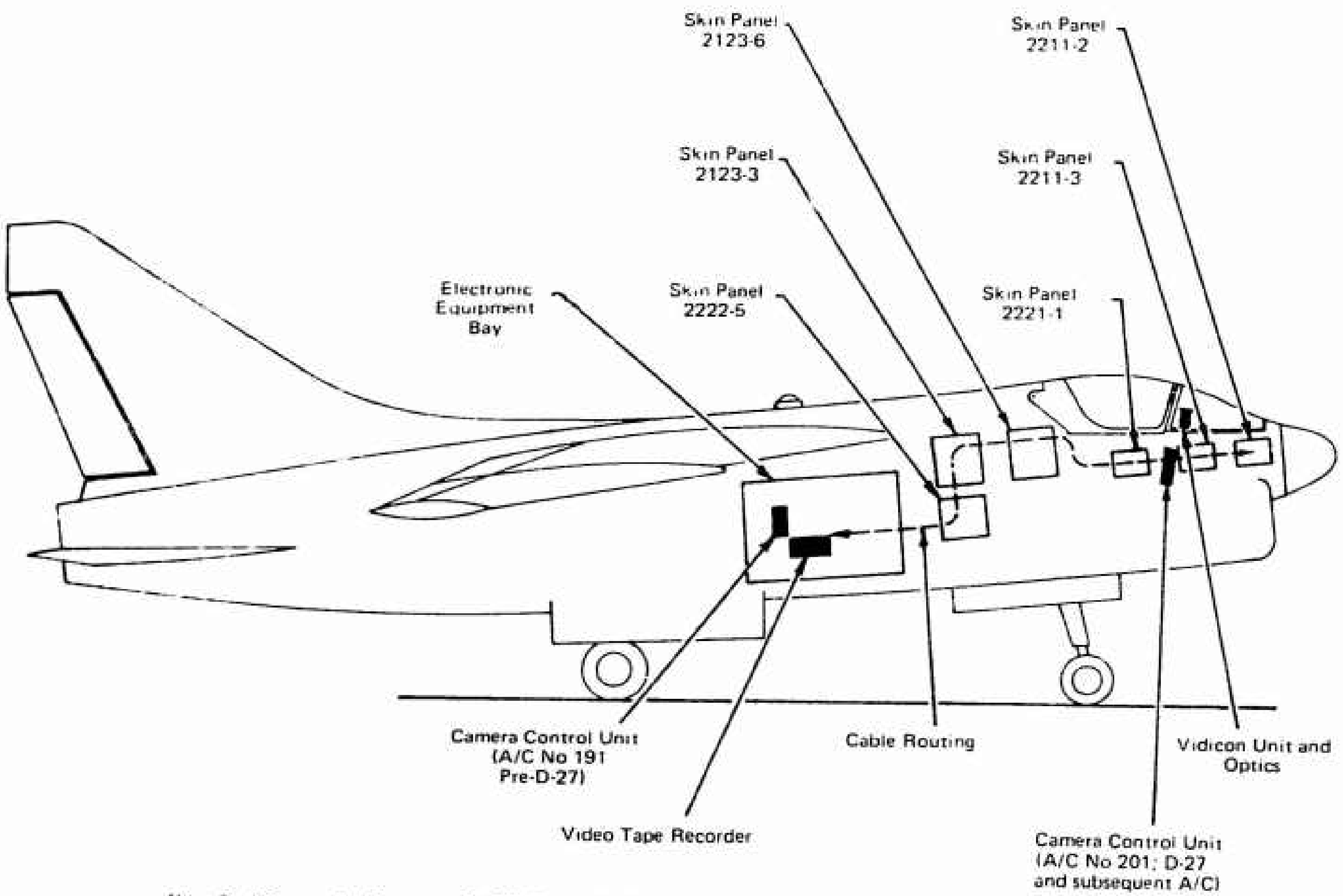

Fig. 2. **Schematic diagram of AVRS installation in the aircraft.**

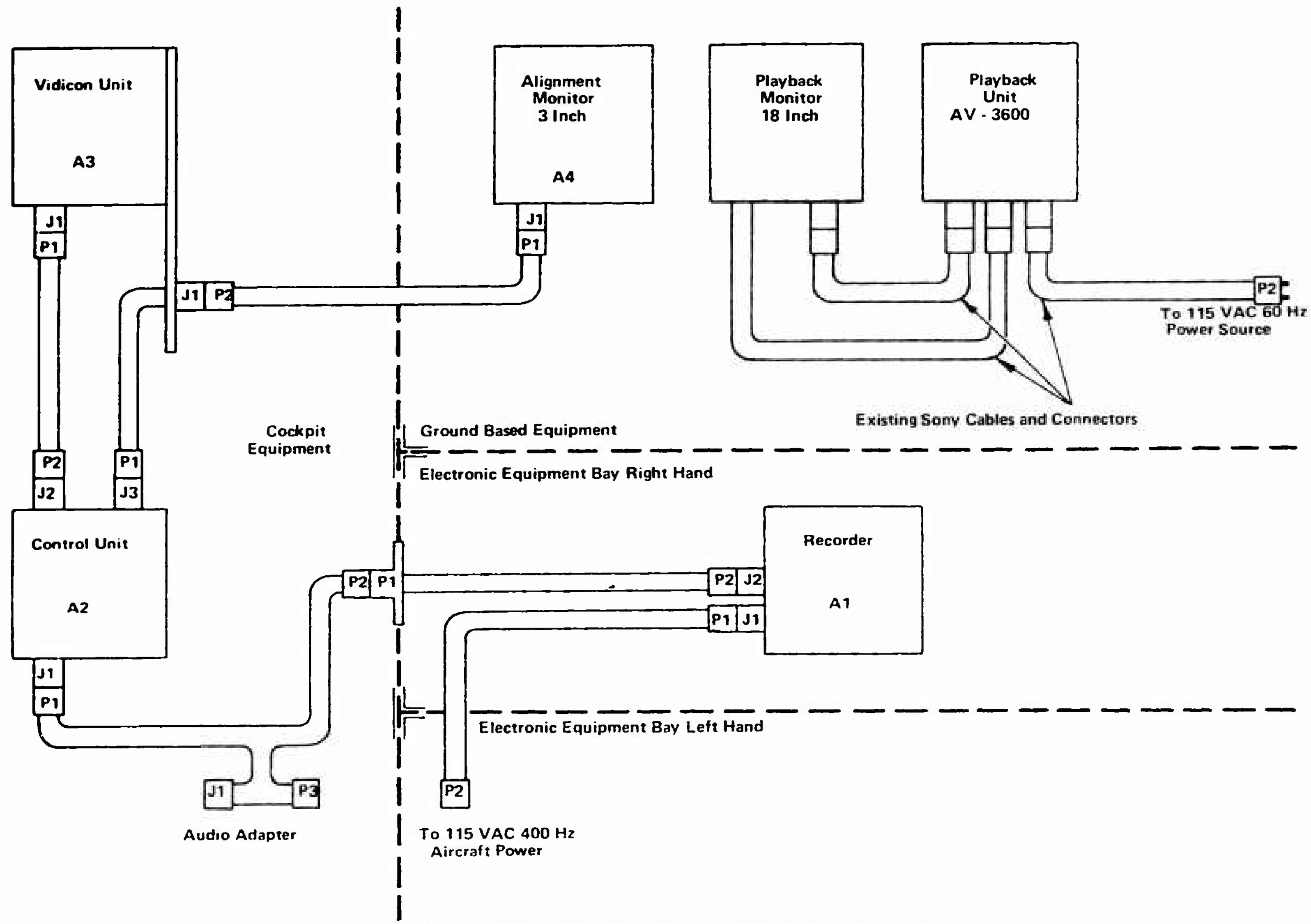

Fig. 3. Schematic diagram of AVRS cable interconnection.

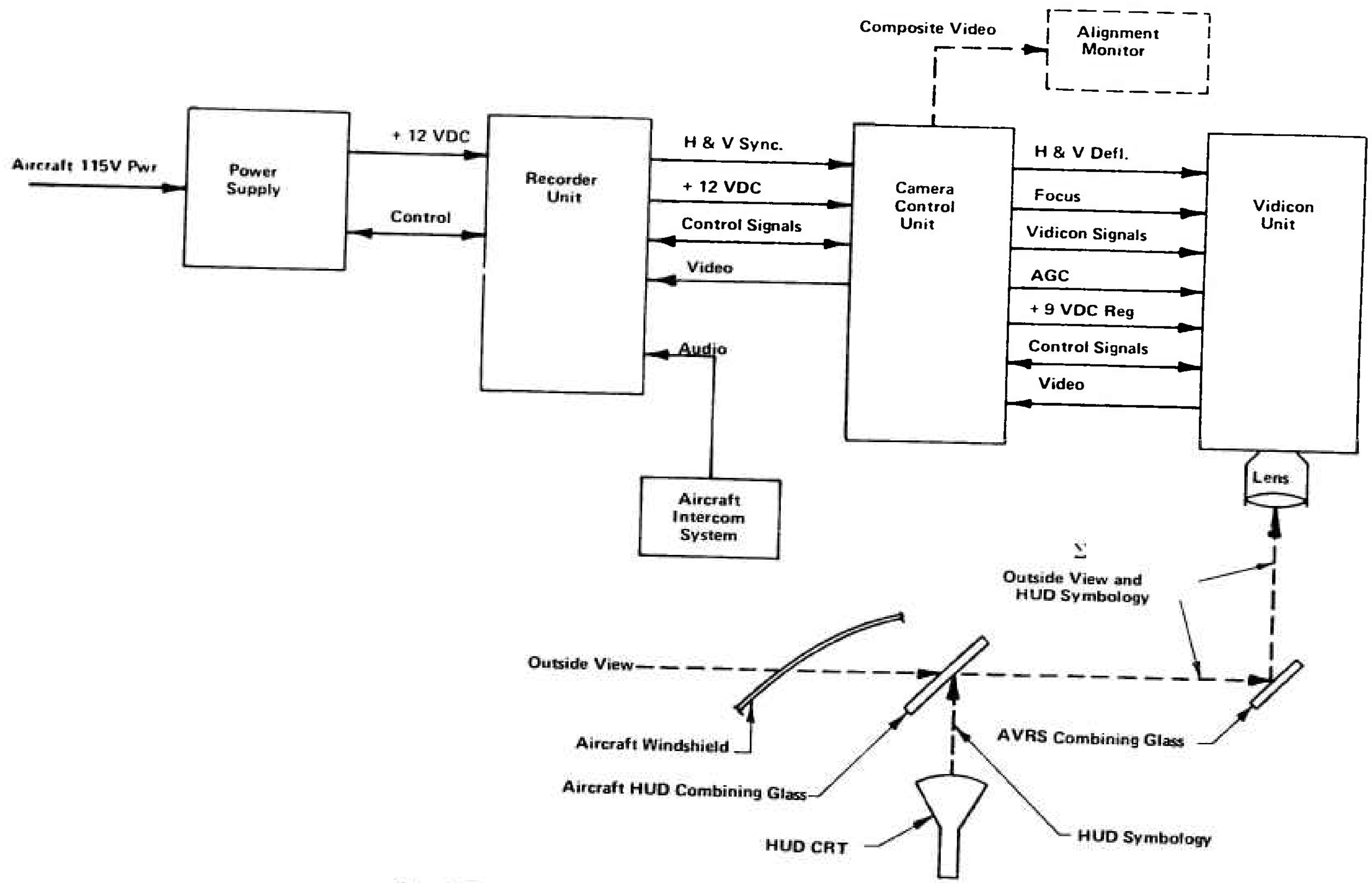

Fig. 4. **Functional block diagram of AVRS.**